Gaze Behaviour and Its Functional Role During Facial Expression Recognition

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Abstract

Processes that underlie the visual encoding of facial expressions still pose a conundrum. Therefore, this dissertation set out to provide new insights into these processes by investigating gaze behaviour and its functional role during the recognition of facial expressions. Specifically, it asked whether general face processing strategies are already reflected on the visual encoding stage and whether differences at the initial uptake of visual information affect facial expression recognition. In order to address these issues, four experimental studies were conducted to measure gaze behaviour while participants were asked to categorise angry, disgusted, happy, sad, and neutral facial expressions in static and dynamic displays. Results are presented in three research manuscripts that are submitted for publication. Studies 1 and 2 served to measure natural gaze behaviour in reaction to static facial expressions by enabling self-paced presentation duration and self-initiated face fixations. Study 3 served to examine the functional role of feature-directed gaze behaviour for the recognition of static facial expressions by comparing recognition performance for emotion-congruent and emotion-incongruent initial fixation positions. Study 4 served to examine gaze behaviour and its functional role for the recognition of dynamic facial expressions by presenting faces either under free viewing or under the instruction to keep gaze in a fixed central fixation position. Results revealed that gaze behaviour for static facial expressions was characterised by only a few fixations mainly directed to the centre and to expression-specific diagnostic facial features of the face. This gaze behaviour suggests a combined holistic and featural encoding strategy. However, for less intense and dynamic facial expressions, results indicated a more configural encoding strategy with multiple fixations to a greater number of inner facial features. In addition, differences in gaze strategy were actually relevant for facial expression recognition. Fixating diagnostic compared to non-diagnostic facial features was beneficial for the recognition of static facial expressions. In contrast, a central fixation position was superior for detecting changes in dynamic facial expressions, presumably by facilitating holistic face processing and change detection. All in all, findings demonstrated that general face processing strategies are reflected on the visual encoding stage of facial expression recognition and that variations in these early processes already affect recognition performance.

Zusammenfassung

Die visuelle Enkodierung emotionaler Gesichtsausdrücke stellt bisher ein Rätsel dar. Ziel der vorliegenden Dissertation war es daher durch die Untersuchung von Blickbewegungen und ihrer Funktionalität für das Erkennen von Gesichtsausdrücken neue Erkenntnisse zu den zugrundeliegenden Prozessen zu liefern. Konkret war die Fragestellung, ob allgemeine Strategien der Gesichterverarbeitung bereits auf der Ebene der visuellen Enkodierung zu identifizieren sind und ob Unterschiede bei der initialen Aufnahme visueller Information das Erkennen von Gesichtsausdrücken beeinflussen. Um dies zu beantworten, wurden in vier experimentellen Studien Blickbewegungen aufgezeichnet, während Probanden ärgerliche, angeekelte, fröhliche, traurige und neutrale Gesichtsausdrücke in statischer und dynamischer Darbietung kategorisieren sollten. Die Ergebnisse wurden in drei Forschungsmanuskripten zusammengefasst und zur Veröffentlichung eingereicht. In Studie 1 und 2 wurde natürliches Blickbewegungsverhalten in Reaktion auf statische Gesichtsausdrücke untersucht, indem eine selbstbestimmte Darbietungsdauer und selbstinitiierte Gesichtsfixationen ermöglicht wurden. Studie 3 untersuchte die Funktionalität merkmalsgerichteter Fixationen für das Erkennen statischer Gesichtsausdrücke, indem die Erkennungsleistung für emotionskongruente und emotionsinkongruente initiale Fixationspositionen verglichen wurde. Studie 4 befasste sich mit Blickbewegungen und ihrer Funktionalität während des Erkennens dynamischer Gesichtsausdrücke, indem Gesichter entweder unter freier Exploration oder unter der Instruktion einer zentralen Fixationsposition präsentiert wurden. Die Ergebnisse zeigten, dass bei statischen Gesichtsausdrücken nur sehr wenige Fixationen gemacht werden, die hauptsächlich auf das Zentrum des Gesichts und auf emotionsspezifische, diagnostische Gesichtsmerkmale gerichtet sind, was eine kombiniert holistisch-merkmalsorientierte Enkodierungsstrategie nahelegt. Für weniger intensive und dynamische Gesichtsausdrücke deuten die Ergebnisse hingegen auf eine stärker konfigurale Enkodierungsstrategie mit mehreren Fixationen zu einer größeren Anzahl innerer Gesichtsmerkmale hin. Darüber hinaus waren Blickbewegungsunterschiede tatsächlich relevant für die Emotionserkennung. Die Fixation diagnostischer im Vergleich zu nicht-diagnostischer Gesichtsmerkmale war für das Erkennen statischer Gesichtsausdrücke vorteilhaft. Für das Erkennen von Veränderungen in dynamischen Gesichtsausdrücken war hingegen eine zentrale Fixationsposition überlegen, vermutlich bedingt durch die Förderung von holistischer Gesichterverarbeitung und Veränderungserkennung. Insgesamt zeigte sich, dass allgemeine Strategien zur Verarbeitung von Gesichtern auf der Ebene der visuellen Enkodierung identifizierbar sind und dass bereits Unterschiede in diesen frühen Prozessen die Erkennungsleistung beeinflussen.

List of Original Manuscripts

MANUSCRIPT 1. "Configural, featural or holistic? An assessment of the visual encoding of facial expressions using self-paced gaze behaviour" by Jonas Dietrich & Ursula Hess (submitted for publication in *Quarterly Journal of Experimental Psychology*)

MANUSCRIPT 2. "Fixations on diagnostic facial features are beneficial for facial expression recognition" by Jonas Dietrich & Ursula Hess (submitted for publication in *Cognition & Emotion*)

MANUSCRIPT 3. "Central fixation position is superior to free viewing for detecting changes in dynamic facial expressions" by Jonas Dietrich & Ursula Hess (submitted for publication in *Acta Psychologica*)

Preface

Human faces are one of the most salient visual stimuli that we encounter in everyday life. They easily attract our attention even when they appear in complex visual scenes (Birmingham, Bischof, & Kingstone, 2008; Theeuwes & Stigchel, 2006). Furthermore, faces are highly important for our social interactions as most social information is communicated face to face. For example, faces carry information about a person's identity, age, gender, or physical attractiveness. Even more important, emotional facial expressions inform us about a person's emotional state and behavioural intentions (Adams, Ambady, Macrae, & Kleck, 2006; Blair, 2003; Horstmann, 2003). Therefore, accurately recognising these expressions is a crucial skill in everyday life as it facilitates social interactions and communication (Hess, Kafetsios, Mauersberger, Blaison, & Kessler, 2016; Niedenthal & Brauer, 2012). Conversely, deficits in the ability to accurately identify facial expressions of emotion are associated with impaired social skills, as in autism (Baron-Cohen & Wheelwright, 2004; Pelphrey et al., 2002), schizophrenia (Hooker & Park, 2002; Loughland, Williams, & Gordon, 2002) or following traumatic brain injury (Bornhofen & Mcdonald, 2008). Therefore, understanding the processes that underlie facial expression recognition is of prime interest.

Facial expression recognition can roughly be divided into two stages of information processing: First, the initial uptake of visual information into our processing system, which is also referred to as visual encoding, and second, the further processing of this information (cf. Schwarzer, Huber, & Dümmler, 2005). So far, research mostly focused on information processing in general (e.g. Calder, Young, Keane, & Dean, 2000; Ellison & Massaro, 1997; Farah, Wilson, Drain, & Tanaka, 1998; Meaux & Vuilleumier, 2016), while only a few studies addressed specific processes on the visual encoding stage of facial expression recognition (e.g. Beaudry, Roy-Charland, Perron, Cormier, & Tapp, 2014; Bombari et al., 2013; Guo, 2012). These studies measured gaze behaviour in order to analyse which information was visually extracted. However, results were often affected by specific viewing conditions that potentially confounded natural gaze behaviour. Furthermore, gaze behaviour per se must not necessarily indicate functional processes for the task at hand as eye movements can be attracted by visual features, irrespective of task demands (Itti & Koch, 2000; Parkhurst, Law, & Niebur, 2002). Thus, the visual encoding of facial expressions still poses a conundrum.

In order to solve this problem, the first goal of this dissertation was to investigate gaze behaviour in an experimental design that minimised confounding viewing conditions during facial expression recognition. In particular, the dissertation asked whether general face processing strategies are already reflected on the visual encoding stage of facial expression recognition. As a second goal, this dissertation aimed to clarify whether differences on the visual encoding stage are actually relevant for the performance in facial expression recognition and therefore whether it is actually meaningful to investigate these processes in order to understand effective facial expression recognition. As facial expressions are usually dynamic in everyday life, the third goal of this dissertation was to investigate whether findings for static displays of emotion generalise to the more naturalistic task of recognising changes in dynamic facial expressions.

In the following section, I will provide an overview about previous research on facial expression recognition, complemented by evidence on eye tracking as a measure of visual attention during facial expression recognition. Based on this overview, I will present my research questions. In the second section of this dissertation, I will give a summary of the empirical work I conducted to address these research questions. In the final section, I will summarise and integrate the findings from my empirical work and finish with critical considerations and ideas for future research.

Facial Expression Recognition

Facial expressions of emotion are considered to convey discrete emotional states (Ekman, 1992). At least six basic expressions have been identified that are universally recognised across cultures: happiness, sadness, disgust, anger, fear, and surprise (Ekman & Friesen, 1975). Each of these expressions consists of specific movements of inner facial features. For example, happiness is typically expressed by uplifted lip corners and raised cheeks, whereas anger is typically expressed by lowered eyebrows and tightened lips (Ekman & Friesen, 1978). In addition, facial expressions reside on a continuum of emotional intensity that ranges from high intense, prototypical facial expressions to subtle, mixed and ambiguous ones.

Despite these variations, humans are remarkably efficient in recognising facial expressions. We usually recognise them above chance level within milliseconds of exposure duration (Calvo & Lundqvist, 2008; Milders, Sahraie, & Logan, 2008; Neath & Itier, 2014). Yet, recognition performance depends on the discrete facial expression, its intensity and whether it is static or dynamic. For example, happy facial expressions are recognised more accurately and more rapidly than all other facial expressions, whereas fearful facial expressions are typically most difficult to identify (Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004). High intense facial expressions are more easily identified than subtle expressions (Guo, 2012; Hess, Blairy, & Kleck, 1997). Dynamic displays of facial expressions facilitate expression recognition compared to static ones (Ambadar, Schooler, & Cohn, 2005; Bassili, 1979). In addition, recognition accuracy increases for longer presentation durations (Calvo & Lundqvist, 2008; Milders et al., 2008).

But how do we actually analyse the emotional content in a face? So far, different approaches have been proposed. According to the *configural approach*, facial expressions are analysed based on the specific configuration of emotional facial features (Calder et al., 2000). Thus, efficient facial expression recognition relies on the integration of structural relationships between inner facial features, e.g. the relative shape and positioning of the mouth in relation to the shape and positioning of eyes and nose. A stronger version of this approach postulated that face processing follows a *holistic process* where facial features are simultaneously integrated into an overall impression of the whole face even without explicitly representing single facial features and their relations (Farah et al., 1998). Evidence for these approaches came, for example, from studies that used face composites with conflicting facial expressions in the upper and lower half of the face. When the face halves were presented in an aligned compared to a misaligned configuration, facial expression recognition was impaired, presumably because participants tried to integrate the conflicting information from both face halves into an overall impression (Calder et al., 2000). In contrast, the *featural approach* postulated that facial expression recognition is based on processing of single facial features that have a diagnostic value for the whole facial expression, such as the smiling mouth for happiness or the frowning eyes for anger (Ellison & Massaro, 1997). In this vein, facial expressions with characteristic facial features in the upper half of the face, e.g. anger and sadness, were best recognised from the eye region, whereas facial expressions with characteristic features in the lower half of the face, e.g. happiness and disgust, were best recognised from the mouth region (Beaudry et al., 2014; Calder et al., 2000; Smith, Cottrell, Gosselin, & Schyns, 2005).

Taken together, the existing literature suggests that facial expression recognition is neither strictly configural nor featural, but instead relies on both – processing of single features and their global configuration (Meaux & Vuilleumier, 2016; Tanaka, Kaiser, Butler, & Le Grand, 2012). However, previous research mostly focused on information processing in general, while evidence on information processing on the visual encoding stage of facial expression recognition is still limited. One way to provide insights into this early stage of information processing is to monitor on-going gaze behaviour. In the following section, I will provide a short methodological overview on the analysis of eye movements as a measure of visual attention.

Eye Movements as an Indicator of Visual Attention

When people inspect a visual stimulus they usually shift gaze between different features. These shifts serve to constantly redirect the fovea. Thereby, the area of high visual acuity can be directed to specific regions of interest, so that detailed visual information is maximised. In general, this gaze behaviour is guided by specific task demands as people move their gaze purposefully to gather goal relevant information (Chen & Zelinsky, 2006; Henderson, 2003; Yarbus, 1967). However, specific stimulus characteristics like contrast, luminance, or overall visual salience are also able to attract eye movements in an automatic manner, irrespective of the task at hand (Itti & Koch, 2000; Parkhurst et al., 2002; Theeuwes, Olivers, & Belopolsky, 2010).

Gaze behaviour is mainly characterised by two types of eye movements: fixations and saccades (Rayner, 1998). During a fixation, the gaze usually remains relatively stable within a fixed gaze position for a duration of approx. 300ms. In contrast, a saccade describes the rapid eye movement between two fixations. Saccades serve to redirect the gaze to new stimulus positions. The duration of a saccade is usually between 30-50ms, depending on the distance covered. Due to the high velocity of a saccade, the uptake of visual information is usually suppressed for that duration (Rayner, 1998). In contrast, fixations are supposed to indicate which information is visually encoded and for how long this information is visually processed (Just & Carpenter, 1976). When people are free to move their eyes, gaze behaviour is usually tightly linked to visual attention (Corbetta et al., 1998; Deubel & Schneider, 1996).

A typical way to record on-going gaze behaviour is by means of an eye-tracker. An eye-tracker tracks people's gaze and computes the running gaze position in relation to the inspected stimulus. In this dissertation, an infrared corneal reflection eye-tracker was used. This type of eye-tracker computes the running gaze position by recording the reflection of an infrared light that is directed at the participants' eyes. For the calculation of eye movements, a fixation was defined as a set of consecutive gaze-point samples that remained relatively stable within a radius of 1° of visual angle around the running gaze-point average (cf. Blignaut, 2009) for a minimum of 100ms (cf. Manor & Gordon, 2003). The location and duration of each fixation on the face was recorded.

In order to relate fixations to specific face regions, faces were divided into seven rectangular areas of interest (AOI), covering the whole face area without overlap or gap: forehead, eye region, nose, left cheek, right cheek, mouth, and chin. All face fixations were classified among these AOIs. As a main measure for the distribution of visual attention to facial features, relative dwell time for each AOI was measured on a trial based calculation by dividing the sum of all fixation durations in a specific AOI by the sum of all fixation durations. Additional fixation measures, such as first fixation time, location of the first or second fixation, and number of different fixated AOIs, served to address specific research questions depending on the particular study.

Eye Movements and Facial Expression Recognition

When people are asked to identify facial expressions of emotion, they usually scan inner facial features such as the eyes, nose and mouth in a triangular fixation pattern with a preference for the eye region (Ebner, He, & Johnson, 2011; Guo, 2012; Vaidya, Jin, & Fellows, 2014). However, at the same time, visual attention is slightly biased to the most informative facial feature of the portrayed facial expression. For example, the general fixation bias towards the eye region is typically increased for facial expressions with diagnostic facial features in the upper half of the face, while it is reduced for facial expressions with characteristic features in the lower half of the face (Bate, Haslam, & Hodgson, 2009; Beaudry et al., 2014; Calvo & Nummenmaa, 2008; Ebner et al., 2011; Guo, 2012; Schurgin et al., 2014). Thus, previous findings suggested a triangular but feature-sensitive gaze strategy for the recognition of facial expressions. Yet, what does this gaze strategy tell us about information processing on the visual encoding stage of facial expression recognition?

In research on facial identity recognition, specific gaze strategies have been linked to specific encoding strategies. For example, a fixation pattern with fixations to multiple facial features, like the triangular fixation pattern, has been linked to a configural encoding strategy. Such a fixation pattern suggests the analysis and integration of featural interrelations between multiple facial features (Bombari, Mast, & Lobmaier, 2009). In contrast, a fixation pattern with increased fixation duration on single facial features has been linked to a featural encoding strategy as it emphasises the intention to maximise detailed information about specific face regions (Bombari et al., 2009; Schwarzer et al., 2005). Thus, when adopting these associations from facial identity recognition to facial expression recognition, the triangular but feature-sensitive gaze strategy in previous eye-tracking research can be linked to a combined configural and featural encoding strategy for facial expression recognition.

Yet, facial expressions can also be well recognised based on only one central face fixation, for which all inner facial features lie within the radius of parafoveal vision and thereby in the area of high visual acuity (e.g. Calvo & Lundqvist, 2008). This finding challenges the necessity of a combined configural and featural encoding strategy for successful facial expression recognition. Furthermore, it suggests the equivalence of a central fixation position that can be linked to a holistic encoding strategy (Bombari et al., 2009; Miellet, Caldara, & Schyns, 2011), which allows the simultaneous encoding of expressive information from different facial features instead of a more time-consuming serial analysis (Bombari et al., 2009; Farah et al., 1998; Schwarzer et al., 2005).

There are several reasons why previous research found a configural and feature-sensitive instead of a more centralised gaze strategy during facial expression recognition. First, previous research often measured gaze behaviour under fixed presentation durations of up to 8000ms (e.g. Bate et al., 2009; Calvo & Nummenmaa, 2008; Ebner et al., 2011; Scheller, Büchel, & Gamer, 2012; Schurgin et al., 2014; Vaidya et al., 2014; Wong, Cronin-Golomb, & Neargarder, 2005). Such fixed presentation durations affect gaze behaviour as they define the number of possible eye movements. In particular, presentation durations that are longer than required might entrain redundant or task-unrelated eye movements, which are likely to be directed to salient facial features that capture visual attention irrespective of task demands (Itti & Koch, 2000; Parkhurst et al., 2002). As a result, gaze might run in a pseudo-configural fixation pattern between the eye and mouth region. To avoid such confounding conditions self-paced presentation duration should be employed.

Second, the majority of previous studies used a central fixation cross and central face presentation (e.g. Bate et al., 2009; Beaudry et al., 2014; Ebner et al., 2011; Guo, 2012; Schurgin et al., 2014; Wong et al., 2005), such that information from the centre of the face is necessarily processed at the beginning of the exploration as the gaze already sets on that location. Consequently, gaze might be less likely to return to this position (cf. Arizpe, Kravitz, Yovel, & Baker, 2012). In addition, some research excluded the first central face fixation from analysis (e.g. Guo, 2012; Schurgin et al., 2014), all in all, resulting in a potential underestimation of the central fixation position. To minimise the confounding role of a central start position, the experimental design should enable a first fixation on the face that is initiated by the participant.

Third, most previous research is limited to the recognition of high intensity, prototypical facial expressions (e.g. Bate et al., 2009; Calvo & Nummenmaa, 2008; Ebner et al., 2011; Scheller et al., 2012; Wong et al., 2005). Yet, prototypical facial expressions might entrain featural gaze behaviour as directing foveal attention to single facial features might suffice to efficiently recognise the whole facial expression. In contrast, less distinct facial expressions might require the integration of information from different facial features to get reliable information about the facial expression, resulting in a less featural fixation pattern (cf. Guo, 2012). To minimise the confounding role of high intense, distinct facial features, research should include facial expressions with varying emotional intensity.

Taken together, the combined configural and featural encoding strategy found in previous research might have been an artefact of the experimental design rather than an indicator for a natural encoding strategy during facial expression recognition. Therefore, it seems highly important to analyse gaze behaviour during facial expression recognition under viewing conditions that allow participants to freely explore the face. Manuscript 1 addresses this issue by analysing eye movements during facial expression recognition under self-paced presentation duration, with different peripheral start positions, and for facial expressions with different emotional intensities.

Functional Role of Eye Movements During Facial Expression Recognition

As describe above, eye tracking indicates where visual attention is directed and which information is visually encoded during facial expression recognition. However, eye tracking per se cannot tell whether the recorded gaze behaviour is actually relevant for facial expression recognition. In everyday life, people usually encounter human faces in viewing distances where all important facial features lie within the radius of parafoveal vision and thereby in the area of high visual acuity. This raises the question to what extent specific gaze strategies could be relevant for facial expression recognition and whether it is actually meaningful to investigate them. Therefore, it seems highly important to examine whether gaze strategy actually has an impact on facial expression recognition.

There are some reasons why specific gaze strategies might be beneficial for facial expression recognition. Although visual acuity is still higher in parafoveal than in peripheral vision, it decreases notably with increasing eccentricity from the central fovea (Loschky, McConkie, Yang, & Miller, 2005). Therefore, direct fixation is typically necessary to identify objects and to perceive their visual details (Henderson, Williams, Castelhano, & Falk, 2003). Thus, perceiving details only in parafoveal or peripheral vision can be associated with a loss in perceptual acuity and therefore with a higher risk for misinterpretations. Furthermore, some facial expressions, such as anger, sadness, disgust, and happiness, are well recognisable from isolated, single facial features (Beaudry et al., 2014; Calder et al., 2000; Calvo & Nummenmaa, 2008). In these cases, focussing on just one single facial feature could be more efficient than scanning all facial features as there is no need to integrate information from different areas of the face.

Up to now, there is only limited evidence on the functional role of gaze behaviour for facial expression recognition. However, a series of findings suggests a processing advantage for fixations on diagnostic facial features. Initial support came from studies that revealed less feature-directed gaze behaviour for specific subpopulations with impaired facial expression recognition, such as participants with schizophrenia (Loughland et al., 2002), autism (Pelphrey et al., 2002), or participants low in empathic traits (Balconi & Canavesio, 2016). Furthermore, correlation analyses showed that better recognition performance was associated with increased visual attention to expression-specific diagnostic facial features (Jack, Blais, Scheepers, Schyns, & Caldara, 2009; Wong et al., 2005).

In addition, directly guiding fixations to expression-specific diagnostic facial features improved recognition performance in clinical subpopulations with a deficit in facial expression recognition (Adolphs et al., 2005; Dadds, El Masry, Wimalaweera, & Guastella, 2008). However, for healthy participants results were less consistent. While priming expression-specific diagnostic facial features had a beneficial effect (Aviezer, Hassin, Perry, Dudarev, & Bentin, 2012), directing gaze to specific feature locations did not affect facial expression recognition (e.g. Neath & Itier, 2014; Scheller et al., 2012). Yet, one limitation of previous research is that studies focused only on recognition accuracy in combination with very brief presentation durations while neglecting possible effects on recognition latency. Manuscript 2 addresses this issue by investigating the effect of feature-directed fixation placement using self-paced presentation duration.

Dynamic Facial Expressions

So far, research on gaze behaviour mainly focused on the recognition of static facial expressions. This is quite understandable as static facial expressions are easier to control under laboratory conditions. However, static displays lack ecological validity, as facial expressions are usually dynamic. In social interactions, facial expressions constantly change and the detection of these changes is a crucial aspect for adjusting behaviour in social interactions (Salovey & Mayer, 1990). Compared to static facial expressions, dynamic displays of emotion facilitate the recognition of facial expressions (Ambadar et al., 2005; Bassili, 1979), are perceived as more intense and arousing (Sato & Yoshikawa, 2007; Weyers, Mühlberger, Hefele, & Pauli, 2006), cause more intense facial mimicry responses (Sato, Fujimura, & Suzuki, 2008; Weyers et al., 2006) and lead to a greater and more widespread activation of brain structures that are typically involved in facial expression recognition (LaBar, Crupain, Voyvodic, & McCarthy, 2003; Trautmann, Fehr, & Herrmann, 2009).

Thus, since static facial expressions are only simplified representations of real stimuli, it is likely that the recognition of dynamic facial expressions poses different task demands. For example, dynamic facial expressions involve more ambiguous levels of expressive information than static facial expressions that are usually presented at the apex of emotional intensity. Therefore, accurately recognising dynamic facial expressions might be less efficient when fixating on single diagnostic features. Instead, it may require monitoring changing featural relations across different face areas. In line with this assumption, recognition of dynamic facial expressions is supposed to involve increased configural processing due to additional Gestalt grouping principals specific to moving stimuli, like common fate or synchrony (Piepers & Robbins, 2012). Conversely, motion in facial expressions facilitated configural face processing at least for happy and disgusted facial expressions (Bould & Morris, 2008). Due to these variations in task demands, gaze behaviour and its functional role might differ as well for the recognition of static and dynamic facial expressions.

However, previous research on dynamic facial expressions provided inconsistent results. Similar to the visual inspection of static facial expressions, the majority of fixations were directed to inner facial features (Bal et al., 2010; Blais, Fiset, Roy, Saumure Régimbald,

& Gosselin, 2017; Buchan, Paré, & Munhall, 2007; Lischke et al., 2012). Yet, an attentional bias to expression-specific facial features emerged only when participants were asked to indicate the onset of a target expression that slowly evolved from a neutral expression (Bal et al., 2010; Lischke et al., 2012). Moreover, the bias emerged only numerically but was not statistically analysed. In contrast, when participants were asked to report the emotion of expressive talking faces (Buchan et al., 2007) or when facial expressions changed rapidly from neutral to full blown expressions (Blais et al., 2017) no bias emerged at all. Thus, additional research is needed to further clarify gaze behaviour during the recognition of dynamic facial expressions. In addition, none of these studies examined the functional role of the observed gaze behaviour. Manuscript 3 addresses these issues.

Research Questions

The objective of this dissertation was to provide new insights into information processing on the visual encoding stage of facial expression recognition by analysing on-going gaze behaviour. As outlined above, previous research on gaze behaviour during facial expression recognition often used viewing conditions that potentially biased natural gaze behaviour. Furthermore, evidence on the functional role of gaze behaviour for the recognition process is still limited, especially for the recognition of dynamic facial expressions. Therefore, this dissertation aimed to extent empirical evidence on gaze behaviour and its functional role for the recognition of static and dynamic facial expressions. The following research questions and related hypotheses guided the empirical work in this dissertation:

1) How are facial expressions visually encoded when viewing conditions allow participants to freely explore the face?
    - Facial expressions are usually identified with response latencies around 1000ms (e.g. Calvo & Lundqvist, 2008). Therefore, I expected self-paced gaze behaviour to be characterised by only few fixations mainly directed to inner facial features that usually convey the emotional content in a face (Ekman & Friesen, 1978).
    - In particular, I expected fixations to be directed to the centre and to expression-specific diagnostic facial features of the face. A central fixation position allows the holistic encoding of expressive information from different facial features instead of a more time-consuming serial analysis (Bombari et al., 2009; Farah et al., 1998; Schwarzer et al., 2005). Therefore, it provides a universal encoding strategy for all facial expressions irrespective of the location of diagnostic facial features. I hypothesised that such an encoding strategy would be especially important for the first fixation on the face (cf. Bombari et al., 2013; Calvo & Nummenmaa, 2008) in order to enable a quick overall impression and to identify relevant facial features for subsequent fixations. As a result, I expected subsequent fixations to be directed towards expression-specific diagnostic facial features in order to increase detailed information about the most informative face regions. In sum, I expected a combined holistic and featural gaze strategy for the visual encoding of static facial expressions.
    - However, for less intense facial expressions, I expected a more configural encoding strategy characterised by an increased number of fixations to multiple facial features due to increased task difficulty and the consequent search and integration of reliable information from multiple face regions (cf. Guo, 2012).

2) Does gaze behaviour play a functional role for the recognition of facial expressions?
    - Direct fixation is usually necessary to identify objects and their visual details (Henderson et al., 2003). In line with this, correlational research (e.g. Wong et al., 2005) and research with clinical subpopulations (e.g. Adolphs et al., 2005) suggested a processing advantage of fixating expression-specific diagnostic facial features. Thus, I expected fixations to diagnostic facial features to improve facial expression recognition. A featural gaze strategy should be especially efficient for facial expressions that are well recognisable from isolated, single facial features.
    - However, healthy participants are remarkably efficient in accurately recognising facial expressions even within milliseconds of exposure duration (e.g. Milders et al., 2008). Accordingly, directing gaze to specific feature locations did not affect recognition accuracy for healthy participants (e.g. Neath & Itier, 2014; Scheller et al., 2012). Yet, previous research focused only on recognition accuracy in combination with very brief presentation durations while neglecting possible effects on recognition latency. As focussing on diagnostic facial feature should increase processing efficiency, I hypothesised that fixations on diagnostic facial features would reduce response latency for accurate facial expression recognition.

3) Do findings for the recognition of static facial expressions generalise to the more naturalistic task of recognising changes in dynamic facial expressions?
    - The recognition of dynamic facial expressions is supposed to involve increased configural processing due to additional Gestalt grouping principals specific to moving stimuli (Bould & Morris, 2008; Piepers & Robbins, 2012). In line with this, previous research revealed gaze behaviour with multiple fixations to all inner facial features (Bal et al., 2010; Buchan et al., 2007; Lischke et al., 2012). Thus, I expected a more configural encoding strategy for the recognition of changes in dynamic facial expressions. However, I also hypothesised that in search of expressive signs of relevant changes, fixations would be additionally biased to face areas with increased emotional activity – i.e., to expression-specific diagnostic facial feature locations.
    - With regard to the functional role of gaze behaviour, I proposed that if gaze behaviour plays a functional role for detecting changes in dynamic facial expressions, recognition performance should be impaired when spontaneous gaze behaviour is disrupted.

Summary of Empirical Studies

In order to address my research questions, I conducted four experimental studies at the psychophysiology laboratory of the Department of Organisational and Social Psychology at the Humboldt-Universität zu Berlin between November 2013 and January 2015. In all studies a Tobii T60 XL Eye-Tracker (Tobii Technology, Stockholm, Sweden) was used to record eye movements while participants were asked to identify angry, disgusted, happy, sad, and neutral facial expressions presented on a computer screen. Studies 1 and 2 served to investigate unrestricted gaze behaviour and related encoding strategies during facial expression recognition. Study 3 addressed the functional role of feature-directed gaze behaviour for the recognition of static facial expressions. Study 4 served to investigate gaze behaviour and its functional role for the identification of dynamically changing facial expressions. Results are presented in three research manuscripts, which are submitted for publication. In the following section, I will provide a short summary of each manuscript.

Manuscript 1: "Configural, Featural or Holistic? An Assessment of the Visual Encoding of Facial Expressions Using Self-Paced Gaze Behaviour" by Dietrich & Hess

The first manuscript focused on the investigation of gaze behaviour under viewing conditions that allowed participants to freely explore the face during facial expression recognition. Specifically, it asked whether gaze behaviour is suggestive of a configural, holistic or featural encoding strategy and whether gaze behaviour varies as a function of emotional intensity.

In two studies, eye movements were recorded in reaction to angry, sad, neutral, happy and disgusted facial expressions. Self-paced presentation duration and different peripheral start positions were used to enable self-initiated gaze behaviour. In Study 1 facial expressions varied in emotional intensity, whereas Study 2 served to investigate the role of an opened vs. a closed mouth in guiding visual attention to the lower half of happy and disgusted facial expressions.

I expected self-paced gaze behaviour to be characterised by only few fixations directed to inner facial features. In contrast to previous research, I expected a less triangular but more centralised fixation pattern as the design avoided viewing conditions that potentially biased fixations to the eye and mouth region. I predicted the nose region to be especially important as a first landing position on the face. In addition, I expected fixations to be biased towards expression-specific diagnostic facial features. I hypothesised that the attentional bias would emerge at least with the second fixation on the face in order to enable an early extraction of the most relevant information (cf. Schurgin et al., 2014). For less intense facial expressions, I expected a more configural fixation pattern. Moreover, I proposed that if visual salience of an opened mouth is involved in guiding visual attention to the lower half of happy and disgusted expressions, visual attention to the lower half should be reduced for closed mouth versions.

Across both studies, participants executed only very few face fixations in order to recognise static facial expressions, and these fixations were almost exclusively directed to inner facial features. Self-paced gaze behaviour revealed a centralised fixation pattern with a high proportion of dwell time on the central nose region, especially for the first fixation on the face. A triangular fixation pattern that included fixations to the eye and mouth region occurred only in one third of all trials. In addition, visual attention was biased to the location of diagnostic facial features. This biased emerged already for the location of the first and second fixation on the face. Less intense facial expressions caused a less centralised and more distributed fixation pattern. Compared to an opened mouth, a closed mouth resulted in less visual attention to the mouth region of happy and disgusted facial expressions. However, visual attention to the eye region was still decreased for both mouth versions.

Overall, findings from this research speak against a general configural encoding strategy characterised by an increased number of fixations to all inner facial features. Rather, results suggest a combined holistic and featural gaze strategy for the visual encoding of facial expressions. For less intense facial expressions, however, gaze behaviour indicated a more configural encoding strategy. In addition, results suggest that a combination of visual salience and expressive information guides visual attention to diagnostic facial features of happy and disgusted expressions.

Manuscript 2: "Fixations on Diagnostic Facial Features Are Beneficial for Facial Expression Recognition" by Dietrich & Hess

The second manuscript focused on the functional role of gaze behaviour for the recognition of static facial expressions. Manuscript 1 revealed that gaze behaviour is sensitive to diagnostic facial features. However, it did not clarify whether this attentional bias was actually helpful for facial expression recognition. Therefore, the goal of this study was to investigate whether differences in the spatial distribution of fixations and therefore differences on the visual encoding stage are actually relevant for facial expression recognition.

For this purpose, the position of initial face fixations was manipulated and participants were asked to categorise angry, disgusted, happy, and sad facial expressions under self-paced presentation duration. The preceding fixation point was either in the eye or in the mouth region of the portrayed facial expression. As a result, the initial fixation position on the face was either congruent or incongruent with the location of diagnostic facial features, depending on the portrayed facial expression. Eye movements were recorded to control for initial fixation position and to analyse gaze behaviour in reaction to congruent and incongruent start fixations.

I expected improved facial expression recognition for congruent compared to incongruent initial fixation positions. I predicted the effect to emerge on recognition latency indicated by shortened response latencies for congruent start fixations. Under the assumption that foveating expression-specific diagnostic facial feature is crucial for facial expression recognition, I further hypothesised that an incongruent compared to a congruent initial fixation position would result in an intensified search and processing of expressive information in the opposite half of the face.

As expected, an initial fixation on diagnostic compared to non-diagnostic facial features resulted in faster response latencies for accurate responses. In addition, initial fixation duration was longer for congruent than for incongruent trials, indicating a preference for processing expression-specific diagnostic facial features. As expected, incongruent initial fixation position resulted in more and longer follow-up fixations in combination with an earlier and more intense exploration of facial features in the opposite half of the face. Furthermore, an earlier exploration of diagnostic facial features in the opposite half of the face after an incongruent start fixation was associated with faster accurate expression recognition.

In conclusion, findings suggest a functional role of eye movements as focusing on diagnostic facial features was beneficial for facial expression recognition. Thus, processes on the visual encoding stage were actually relevant for facial expression recognition. In addition, the findings emphasise the importance of featural processing for efficient facial expression recognition.

Manuscript 3: "Central Fixation Position Is Superior to Free Viewing for Detecting Changes in Dynamic Facial Expressions" by Dietrich & Hess

The third manuscript focused on whether findings for the recognition of static facial expressions generalise to the more naturalistic task of recognising changes in dynamic facial expressions.

To this end, participants were asked to identify the target expression in dynamic displays that changed from one facial expression into another (cf. Hugenberg & Bodenhausen, 2003; Sacharin, Sander, & Scherer, 2012). For this purpose, angry, disgusted, happy, sad and neutral facial expressions were morphed into each other to create dynamically changing facial displays. Eye movements were recorded while participants were asked to identify the target expression in a between-subject design. One participant group explored facial expressions under free viewing, while the other received the instruction to keep gaze in a fixed central fixation position (cf. Henderson, Williams, & Falk, 2005). The central fixation position restricted spontaneous gaze behaviour while allowing participants to perceive all facial features with sufficient visual acuity as all features lay within the radius of parafoveal vision. In order to examine the functional role of spontaneous gaze behaviour, recognition performance was compared for free and restricted viewing.

I expected fixations to follow a configural fixation pattern with multiple fixations to all inner facial features. However, due to the diagnostic value of the eye region for the detection of anger and sadness and the mouth region for the detection of happiness and disgust, I expected an additional fixation bias to diagnostic facial features of the target expression. Moreover, if gaze behaviour plays a functional role for detecting changes in dynamic facial expressions, I proposed that recognition performance should be better under free viewing than under restricted viewing. However, if gaze behaviour does not play a functional role, recognition performance should not differ.

As expected, spontaneous gaze behaviour ran in a triangular fixation pattern between eyes, nose and mouth with an additional fixation bias to diagnostic facial features of the target expression. However, restricting gaze behaviour to a central fixation position not only did not affect recognition accuracy, but instead improved recognition latency compared to free viewing.

In conclusion, results suggest a configural but feature-sensitive encoding strategy for the detection of changes in dynamic facial expressions under free viewing. However, such a spontaneous feature-directed gaze strategy was less beneficial compared to a central fixation position that presumably elicited holistic face processing and facilitated change detection.

Discussion

So far, information processing on the visual encoding stage of facial expression recognition posed a conundrum. Therefore, this dissertation set out to provide insights into these early processes by measuring on-going gaze behaviour. Four studies were conducted to investigate gaze behaviour and its functional role during the recognition of facial expressions with varying emotional intensities in static and dynamic displays. Studies 1 and 2 (Manuscript 1) served to investigate gaze behaviour under viewing conditions that enabled self-paced gaze behaviour. In Study 3 (Manuscript 2), recognition performance was compared for facial expressions that were presented either with expression-congruent or expression-incongruent initial fixation positions. Finally, Study 4 (Manuscript 3) served to examine gaze behaviour and its functional role during the recognition of dynamically changing facial expressions either under free viewing or under the instruction to keep gaze in a fixed central fixation position. In the following sections, I will summarise and integrate the findings from all four studies. I will finish the dissertation with critical considerations and ideas for future research.

Gaze Behaviour During Facial Expression Recognition

Previous eye tracking research often suffered from viewing conditions that potentially confounded natural gaze behaviour during facial expression recognition, for example by fixed presentation durations, central start fixation positions or the exclusive use of high intense prototypical facial expressions. Therefore, the first goal of this dissertation was to investigate gaze behaviour during facial expression recognition under viewing conditions that allowed participants to freely explore the face.

In Studies 1 and 2, self-paced presentation duration and peripheral start positions were used to enable natural gaze behaviour during facial expression recognition. Under these conditions, participants needed on average only three fixations to identify the portrayed facial expression. As average fixation duration was about 300ms, results are in line with findings that facial expressions are usually identified within approx. 1000ms (Calvo & Lundqvist, 2008; Palermo & Coltheart, 2004). This result challenges previous eye tracking research using longer presentation durations (e.g. Bate et al., 2009; Ebner et al., 2011; Wong et al., 2005) as additional fixations might have been redundant or task-unrelated. Conversely, it emphasises the importance of using self-paced presentation duration in order to measure natural gaze behaviour.

As expected, visual attention was almost exclusively directed to inner facial features such as the eyes, nose, and mouth (cf. Guo, 2012; Vaidya et al., 2014), that is, to features that typically convey the emotional content in a face (Ekman & Friesen, 1978). Among these inner facial features, the nose region received a relatively high percentage of dwell time, especially for the initial fixation on the face, even though the nose region typically conveys less expressive information than the eye or mouth region (cf. Ekman & Friesen, 1978). This finding is in line with previous research using peripheral start positions (e.g. Calvo & Nummenmaa, 2008) and emphasises the importance of the nose region as a preferred landing position on the face. Thus, when we direct our gaze to a person's face in order to identify its facial expression, we initially focus on the centre of the face.

In addition, Studies 1 and 2 revealed that the distribution of visual attention to inner facial features varied with the location of diagnostic facial features. As in previous research (e.g. Beaudry et al., 2014; Ebner et al., 2011; Guo, 2012; Schurgin et al., 2014), visual attention to the eye region was highest for facial expressions with diagnostic facial features in the upper half of the face, i.e. for angry and sad expressions, while visual attention to the mouth region was highest for facial expressions with diagnostic facial features in the lower half of the face, i.e. for happy and disgusted expressions. The distribution of visual attention for neutral facial expressions, however, was less biased to either eye or mouth region (cf. Bate et al., 2009; Ebner et al., 2011), reflecting the absence of emotional content in either half of the face. The attentional bias occurred already at the very beginning of the visual exploration (cf. Bombari et al., 2013; Schurgin et al., 2014). Even the first fixation on the face showed a slight bias towards the location of diagnostic facial features (cf. Calvo & Nummenmaa, 2008). This is astonishing as facial information was only accessible from peripheral vision prior to the first fixation on the face. Thus, participants used facial information from peripheral vision to guide first fixations to the most informative facial features. The attentional bias was further accentuated for the second fixation on the face. In sum, findings suggest the importance of focussing on the most relevant facial features as early as possible during facial expression recognition.

The attentional bias to diagnostic facial features was further replicated by findings from Studies 3 and 4. Study 4 revealed an almost identical bias, although facial expressions were presented in dynamic displays that changed from one facial expression into another. In Study 3, the attentional bias was reflected in a longer initial fixation duration when the fixation lay on a diagnostic compared to a non-diagnostic facial feature. In addition, visual attention to diagnostic facial features in the opposite half of the face was increased when the initial fixation lay on a non-diagnostic feature. Taken together, the attentional bias to expression-specific diagnostic facial features was shown in four different studies with diverse facial stimuli. Therefore, my research strongly suggests that processing of facial expressions is sensitive to the most informative facial features and that this is already the case at the initial uptake of information into our visual system.

However, facial features do not only vary in expressive information but also in visual salience depending on the portrayed facial expression, for example, due to an opened vs. a closed mouth. As a consequence, increased visual attention to the mouth region of happy and disgusted expressions might have been a result of increased visual salience due to the whiteness of the teeth instead of diagnostic information itself (cf. Calvo & Nummenmaa, 2008). Study 2 addressed this issue by presenting both expressions with an opened and a closed mouth. Visual attention was indeed less biased to the mouth region of happy and disgusted facial expressions when they were presented with a closed compared to an opened mouth. Thus, visual attention directed to the mouth region was in part guided by visual salience. However, visual attention to the eye region was still decreased for both mouth versions compared to angry, sad and neutral expressions. This is in line with research showing reduced visual attention to the eye region of happy compared to fearful and neutral expressions even though stimuli were matched in visual salience of the eye and mouth regions (Scheller et al., 2012). In addition, Study 4 revealed an attentional bias to expression-specific diagnostic facial features in the eye or mouth region, although all facial expressions were presented with a closed mouth. In sum, my findings complement previous research and suggest that it is not visual salience alone but a combination of visual salience and expressive information that guides visual attention to diagnostic facial features.

In addition, my research revealed that gaze behaviour differs as a function of the emotional intensity of facial expressions. In everyday social life, we usually encounter facial expressions with a great range of different emotional intensities. Therefore, I was interested in whether gaze behaviour follows a universal fixation pattern or whether it is adjusted to varying task demands depending on different levels of emotional intensity. I hypothesised that the recognition of less intense facial expressions would require a more distributed fixation pattern due to increased task difficulty and the consequent search and integration of reliable information from multiple facial features. So far, the existing literature provided only inconsistent results. Whereas Schurgin et al. (2014) found decreased visual inspection of expression-specific diagnostic facial features for less intense facial expressions, Vaidya et al. (2014) found feature-biased gaze behaviour only for subtle but not for extreme facial expressions. Furthermore, Guo (2012) failed to find any effect of emotional intensity on the spatial distribution of visual attention during facial expression recognition. My research provides new insights into these processes and suggests that gaze behaviour is indeed adjusted to varying task demands. When confronted with less intense facial expressions in Study 1, participants made more but shorter fixations and looked at the face for a longer duration compared to high intense facial expressions. In addition, participants fixated a greater number of different facial features and gaze behaviour was generally less centralised for less intense facial expressions. Thus, instead of focussing on the centre of the face, participants gathered information from different facial features. As expected, the recognition of less intense facial expressions was associated with an intensified search for and integration of information from multiple facial features. At first glance, this is in line with Schurgin et al. (2014) who reported a less feature-biased fixation pattern for less intense facial expression. However, in my research, emotional intensity did not change the way people focused on diagnostic facial features as the proportion of dwell time directed to these features was unaffected by emotional intensity. Rather, results suggested that participants still focused on diagnostic facial features but additionally included facial information from multiple facial features at the expense of fixations to the centre of the face. Thus, participants adjusted their gaze behaviour to varying task demands associated with different levels of emotional intensity. Therefore, it seems likely that people also adjust gaze behaviour with the same flexibility when they encounter facial expressions in everyday social life.

Gaze Strategy for the Visual Encoding of Facial Expressions

So what do the above findings tell us about information processing on the visual encoding stage of facial expression recognition? When adopting the associations between gaze behaviour and processing strategies from research on facial identity recognition, Studies 1 and 2 suggest a combined holistic and featural encoding strategy for the recognition of static facial expressions - *holistic* because of the high percentage of initial dwell time on the central nose region and *featural* because of the subsequent bias to expression-specific diagnostic facial features. The initial central fixation position increases the amount of expressive information that can be attended to simultaneously (cf. Bombari et al., 2009; Miellet et al., 2011; Schwarzer et al., 2005) and enables a quick, overall impression of the whole face likely to direct further fixations to relevant facial features. These additional featural fixations increase the detailed information about single facial features that are crucial for efficient facial expression recognition.

In addition, Studies 1 and 2 revealed that in most trials only two different facial features, typically the nose plus either the eyes or the mouth, were fixated. For one quarter of all presented facial expressions, participants focused only on one single facial feature. In contrast, a fixation pattern that included fixations to the eye *and* mouth region occurred only in one third of all trials. These results contradict the notion of a general configural encoding strategy characterised by a triangular fixation pattern with multiple fixations to all inner facial features. On the contrary, my research suggests that configural gaze behaviour in previous research was an artefact of confounding viewing conditions rather than an indicator for a natural encoding strategy. This finding in is line with research on facial identity recognition showing that two fixations directed to the centre of the face are also sufficient to recognise a person's identity (Hsiao & Cottrell, 2008). Together, the results challenge the necessity of the often-reported triangular fixation pattern for successful face processing.

However, for less intense facial expressions, the results on gaze behaviour suggest a more configural encoding strategy as visual attention was less centralised and the number of fixations to multiple facial features was increased. This assumption was further complemented by findings for dynamic facial expressions. Similar to less intense facial expressions, dynamic facial expressions usually involve more ambiguous states of expressive information. In this vein, Study 4 revealed a clear configural encoding strategy with multiple fixations to all inner facial features for the recognition of dynamic facial expressions (cf. Bombari et al., 2009; Guo, 2012). However, in both cases the featural gaze component was unaffected. In Study 1, the proportion of dwell time directed to expression-specific diagnostic facial features did not vary as a function of emotional intensity. In Study 4, an attentional bias to expression-specific diagnostic facial features emerged despite the use of dynamic facial expressions. Thus, expressive ambiguity changed the holistic gaze component into a more configural one but did not affect additional featural processing.

Taken together, visual encoding during facial expression recognition was characterised by a combination of gaze strategies that varied with emotional intensity and facial movement. In any case, visual encoding included a featural gaze component. However, depending on task demands, it was either accompanied by additional holistic or configural encoding. Yet, holistic processing is often considered as a specific case of configural processing (Bartlett, Searcy, & Abdi, 2003; Leder & Bruce, 2000; Maurer, Grand, & Mondloch, 2002). Therefore, it is likely that both gaze strategies served to additionally encode the overall configuration of inner facial features.

In general, the observed gaze behaviour is in line with current models of face processing assuming that facial expression recognition relies on both – processing of single features and their integration into a global whole (Meaux & Vuilleumier, 2016; Tanaka et al., 2012). Nonetheless, my research demonstrated that these processing strategies are already reflected on the visual encoding stage of facial expression recognition.

Functional Role of Gaze Behaviour for Facial Expression Recognition

Findings from all four studies demonstrated that processing of facial expressions varies already at the initial uptake of information into our visual system. Yet, this variation per se cannot tell whether differences on the visual encoding stage are actually relevant for the performance in facial expression recognition. To my knowledge, this dissertation represents the first attempt to systematically investigate the functional role of gaze behaviour for facial expression recognition in healthy participants. Studies 3 and 4 addressed this issue by directly manipulating gaze behaviour during the recognition of static and dynamic facial expressions.

In Study 3, initial fixations to expression-specific diagnostic compared to non-diagnostic facial features facilitated facial expression recognition as response latencies for accurate responses were reduced. Thus, the position of the first fixation affected facial expression recognition. In addition, an earlier exploration of diagnostic facial features in the opposite half of the face after an initial fixation on non-diagnostic facial features was correlated with faster response latencies for accurate responses. Thus, for the recognition of static facial expressions it was actually helpful to focus on expression-specific diagnostic facial features. These results complement previous research showing a functional relationship for clinical subpopulations (Adolphs et al., 2005; Dadds et al., 2008; Loughland et al., 2002; Pelphrey et al., 2002) and in correlation analyses (e.g. Jack et al., 2009; Wong et al., 2005). Furthermore, they demonstrate that differences in gaze behaviour actually affect facial expression recognition.

Study 4 represents the first attempt to investigate the functional role of gaze behaviour for the recognition of dynamic facial expressions. It revealed that restricting gaze behaviour to a central fixation position improved recognition performance in contrast to free viewing. The latency for accurately recognising changes in dynamic facial expressions was significantly reduced. Thus, for the recognition of dynamic facial expressions, it was beneficial to fixate the centre of the face. Again, performance in facial expression recognition varied with gaze strategy.

Taken together, my research demonstrated that processes on the visual encoding stage are indeed relevant for the performance in facial expression recognition. Thus, it is important to investigate these processes in order to understand effective facial expression recognition.

Furthermore, my research suggests that people can improve their facial expression recognition skills by adjusting their gaze strategies. These findings are in line with results for other face processing tasks. For example, directing fixations to specific facial features reduced the own race bias (Hills & Lewis, 2011) and the face-inversion effect (Hills, Ross, & Lewis, 2011) in face identity recognition. Conversely, restricting gaze behaviour to specific face region impaired face recognition (Henderson et al., 2005; Hsiao & Liu, 2012). In conclusion, gaze strategies affect the perception and processing of faces and facial expressions of emotion.

Findings for Dynamic Facial Expressions

Finally, this dissertation asked whether findings for the recognition of static facial expressions generalise to the more naturalistic task of recognising changes in dynamic facial expressions. Almost all existing evidence on gaze behaviour is limited to the recognition of static facial expressions, although facial expressions are usually dynamic. Previous research emphasised the ecological validity of dynamic compared to static displays of facial expressions (e.g. Ambadar et al., 2005; Sato et al., 2008; Trautmann et al., 2009; Weyers et al., 2006). Therefore, it seemed highly important to analyse gaze behaviour for dynamic facial expressions in order to understand the visual encoding of facial expressions in everyday social life.

My research confirmed an attentional bias to expression-specific diagnostic facial features not only for the recognition of static facial expressions but also for dynamic facial expressions. In Study 4, eye movements were preferentially directed to the eye region when faces changed into angry and sad expressions and to the mouth region when faces changed into happy and disgusted expressions. Thus, featural encoding also played a part in the recognition of dynamic facial expressions.

However, gaze behaviour also differed between static and dynamic displays. Whereas the recognition of static facial expressions involved additional holistic gaze behaviour, recognising dynamic facial expressions involved an additional configural gaze strategy with multiple fixations to all inner facial features. This is in line with research suggesting that the recognition of dynamic compared to static facial expressions involves increased configural processing (Bould & Morris, 2008; Piepers & Robbins, 2012). However, as mentioned above, both gaze strategies might have served to additionally encode the overall configuration of inner facial features.

Another fascinating difference between static and dynamic facial expressions emerged with respect to the functional role of gaze behaviour. Whereas fixating diagnostic compared to non-diagnostic facial features was beneficial for the recognition of static facial expressions, recognising changes in dynamic facial expressions was facilitated by a central fixation position compared to spontaneous gaze behaviour that included fixations to expression-specific diagnostic facial features. Differences might be explained by different task demands. For the recognition of static facial expressions, it might be sufficient to focus on single facial features, especially as participants were asked to identify facial expressions that are well recognisable from isolated, single facial features (Beaudry et al., 2014; Calder et al., 2000; Calvo & Nummenmaa, 2008). In this case, increasing detailed information about these features might be more efficient as there is no need to integrate information from different areas of the face. In contrast, detecting changes in dynamic facial expressions requires constant monitoring of featural relations across different areas of the face. This process potentially favours a holistic gaze strategy elicited by a central fixation position (Bombari et al., 2009; Miellet et al., 2011; Schwarzer et al., 2005) as a central fixation increases the amount of facial information that can be attended to simultaneously. Accordingly, a central fixation position may prevent observers from missing relevant changes in one half of the face while looking at the other half. In addition, a central fixation position reduces the amount of possible saccades and therefore the possibility of missing changes during saccadic suppression of information extraction (Rayner, 1998). However, additional research is needed to clarify whether an initial central fixation position would also be equivalent or even superior for the recognition of static facial expressions.

In sum, my findings indicate that static and dynamic displays of facial expressions elicit slightly different gaze strategies. Furthermore, gaze strategies for efficient facial expression recognition varied as a function of task demands. Whereas the recognition of static facial expressions was facilitated by featural fixations, the more naturalistic task of detecting changes in dynamic facial expressions was facilitated by a holistic gaze strategy. Thus, my findings highly recommend to extend research on gaze behaviour to dynamic facial expressions in order to fully understand the visual encoding of facial expressions in everyday social life.

Critical Considerations and Future Research

In the above sections, I outlined how my research provided new insights into information processing on the visual encoding stage of facial expression recognition. Yet, a few critical considerations have to be mentioned.

Although static facial expressions can usually be recognised with sufficient accuracy in case of only one central face fixation (e.g. Calvo & Lundqvist, 2008), gaze behaviour was additionally directed to other face locations in the majority of trials. In Studies 1 and 2, gaze stayed exclusively within the central nose area in only 8% of all trials. Similarly, Study 4 revealed a spontaneous fixation pattern that included multiple fixations to all inner facial features, although findings under restricted viewing demonstrated improved recognition performance in case of only one central fixation position. This raises the question why participants actually executed the observed gaze behaviour.

In general, gaze behaviour is mainly dominated by task demands (Chen & Zelinsky, 2006; Henderson, 2003; Yarbus, 1967). However, specific stimulus characteristics like contrast, luminance, or overall visual salience are also able to attract eye movements in an automatic manner irrespective of the task at hand (Itti & Koch, 2000; Parkhurst et al., 2002; Theeuwes et al., 2010). Therefore, the observed gaze behaviour might have been a result of stimulus-driven rather than task-driven effects. For example, in Studies 1 to 3, additional fixations to salient facial features might just have reflected a default mode while the observer was reaching a decision based on the information from the first impression. Similarly, the triangular fixation pattern in Study 4 might have been the consequence of long presentation durations combined with relatively slowly changing facial expressions. In fact, research using a higher changing velocity reported a more centralised fixation pattern for dynamic compared to static facial expressions (Blais et al., 2017). In addition, the high proportion of first fixation on the centre of the face in Studies 1 and 2 might have reflected the tendency to fixate the centre of gravity when orienting gaze to a face rather then a holistic gaze strategy (cf. Bindemann, Scheepers, & Burton, 2009).

Yet, some arguments speak against purely stimulus-driven gaze behaviour in the present dissertation. First, participants received the instruction to identify the portrayed facial expression in all four studies. Thus, stimulus-driven effects should have been reduced as task-driven effects usually prevail (Chen & Zelinsky, 2006; Henderson, 2003; Malcolm, Lanyon, Fugard, & Barton, 2008; Yarbus, 1967). Second, all instructions emphasised fast expression recognition, which should have forced participants to direct their gaze to the most informative face regions in order to extract the expressive information with minimum time. Third, additional fixations to diagnostic facial features in the opposite half of the face, when initially fixating non-diagnostic facial features, were actually beneficial for facial expression recognition in Study 3. Thus, additional fixations in Studies 1 and 2 might have served to verify the first impression of the facial expression. However, future research is needed to clarify whether additional fixations are indeed beneficial, for example by varying the number of possible fixations during facial expression recognition (cf. Hsiao & Cottrell, 2008). Fourth, previous research reporting a more centralised fixation pattern for dynamic compared to static facial expressions presented facial expressions only for 500ms in combination with a central start fixation point (Blais et al., 2017). As a result, the possibility for fixations to leave the central fixation position was reduced in general. In addition, facial expressions in the static condition were presented at the apex of emotional intensity for the whole presentation duration, whereas dynamic facial expressions evolved from neutral to full-blown expressions over time. Therefore, the tendency to leave the central fixation position in favour of other expressive features might have been increased for static compared to dynamic displays. As a result, gaze behaviour for dynamic facial expressions might have resembled a more centralised fixation pattern. Finally, Study 4 revealed a relatively high percentage of trials in which participants could not maintain the required central fixation position under restricted viewing (25% of trials). Thus, people seem to have a natural impulse to leave the central fixation position. Therefore, a fixation pattern including additional fixation positions might just reflect the best compromise between the need to adjust gaze behaviour to specific task demands and the natural impulse to focalise salient facial features.

One limitation of the present dissertation concerns the selection of facial expressions. In order to relate gaze behaviour to distinct facial feature locations, I chose facial expressions that are characterised either by diagnostic facial features in the upper (i.e. angry, sad) or in the lower (i.e., happy, disgusted) half of the face (Beaudry et al., 2014; Calder et al., 2000; Smith et al., 2005). As surprise and fear are typically characterised by diagnostic facial features in both face halves (Bassili, 1979; Beaudry et al., 2014; Ekman & Friesen, 1978), they were not included in the present research. Therefore, future research is needed to extent the present findings to more complex facial expressions.

Finally, facial expression recognition in everyday life is usually linked to a specific social context. Therefore, as a next step, future research should ask whether top-down processes like expectations or stereotypes influence gaze behaviour during facial expression recognition. A few studies already suggest such a relationship. For example, body posture is able to affect gaze behaviour in reaction to attached facial expressions (Aviezer et al., 2008) and the expectation of a specific facial expression seems to increase visual attention to the expected diagnostic facial feature location (Bombari et al., 2013; Herwig & Horstmann, 2011). Thus, it seems important and promising to follow this idea in order to further understand information processing during facial expression recognition in everyday social interactions.

Conclusion

All in all, this dissertation shed light upon the conundrum of the visual encoding of facial expressions. It provided new insights into the early stage of information processing by investigating gaze behaviour and its functional role during the recognition of static and dynamic facial expressions. Taken together, findings demonstrated that general face processing strategies are reflected during the initial uptake of facial information into our visual system and that differences in these early processes already affect facial expression recognition.

Visual encoding of facial expressions turned out to be based on two primary gaze components – one that focuses on expression-specific diagnostic facial features and one that addresses the interrelations between facial features. However, the exact gaze strategy and its benefit for facial expression recognition varied with the type of facial expression. Recognising static facial expressions involved only a few fixations directed to the centre and to expression-specific facial features. Furthermore, directing gaze to these features actually improved facial expression recognition. In contrast, recognising dynamic facial expressions involved more fixations to all inner facial features. However, directing gaze to a central fixation position was superior for recognising changes in these facial expressions. Overall, my results suggest that there is no universal encoding strategy for facial expression recognition but that people flexibly adjust gaze behaviour to actual task demands.

The present work extends our knowledge as it minimised confounding viewing conditions in order to investigate natural gaze behaviour during the recognition of facial expressions. In addition, it focused on gaze behaviour in reaction to a greater variety of facial expressions. Thus, findings are more comparable to facial expressions that people encounter in everyday life. Moreover, my research represents the first attempt to systematically investigate the functional role of gaze behaviour for the recognition process. As a result, the present findings contribute to a better understanding of processes that underlie effective facial expression recognition and help to identify gaze strategies that improve facial expression recognition in everyday social interactions.

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